SCIENCE:

A Weekly Record of Scientific Progress.

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Two or three weeks ago we complained of the coldness of British writers in neglecting to recognize and acknowledge the full scientific value of Bell's and Edison's discoveries, and we condemned, more particularly, their omission from Gordon's illustrated catalogue of recent advances in electrical science, which had then just appeared in London. To day, after having read a four column pean of eulogy and encomium on Prof. Bell and his Photophone, in the last number of *Engineering* we make a candid confession, that, in order to arrive at the real estimate of an American discovery in the average English mind, it is indispensable that the 'mean' of English criticism should first be drawn.

The concluding paragraph of this article reads as follows: "Who can say to what great fields of science this one discovery of Prof. Bell may not lead, fields of research not limited in locality to this earth, but reaching to the planets, and to the farthest limits of visible stellar space. It is by a beam of light that the modern astronomer is able to analyse the chemical constitution of the farthest stars and nebulæ, and is enabled to detect and to deal with metallic vapors through distances of thousands of millions of miles as surely as in his own laboratory, who, after Prof. Bell's experiments will have the hardihood to affirm that sounds taking place in the far off regions of the universe may not one day be heard on the earth, and new fields of acoustical astronomy may not be opened to the intelligence of man. When such a time arrives, the thought of the poet will be clothed with the truth of the fact, that "Light is the voice of the stars."

In the same strain which excites *Engineering* to this transcendental flight of fancy, may we not also hope, in the future, to catch the whisperings of Venus as she waltzes among her heavenly companions, and if we dare to reach so far in our aspirations for the perfection of the Photophone, may we not yet be able to hear the reflections of light, mixed with heat, which Mars, an ardent admirer of old, throws to that splendid luminary as they near each other? It is also true that Mr. Edison has helped to begin that sort of business; for did he not, long since, catch the warmth of the coronal beams, when the sun withdrew behind fair Luna's screen, and didn't Mr. Lockyer (who was there) tell us all that happened? Let us not, however, go too far and admit that the era has arrived which Gulliver predicted, when he discribed the process of the philosopher of Laputa who extracted sunbeams out of cucumbers.

Engineering should know that the Photophone is but a simple machine for registering heat waves that have impinged upon a piece of hard rubber, and that these waves, originally set in motion by the voice, when made to act on any material expansible by heat, will reproduce, more or less effectually, the original motion which gave them birth. Such an instrument is the Tasimeter, which Professor Bell has stripped of its swaddling clothes and made to talk.

CONSIDERABLE alarm has been created among those interested in horse flesh by certain reports circulated regarding a new so-called epizootic among horses. We have been at some pains to collect reliable *data* concerning this matter, and have found, as we anticipated, that its importance is greatly exaggerated by enterprising reporters of daily papers. We have become satisfied of the fact that the distemper now prevailing in New York, has nothing in common with the epizootic which was such a memorable feature of the year 1873, and so severe a one that hardly a carriage could be seen on our streets, while but few of the horse-car lines were able to keep their conveyances running with any regularity.

Veterinarians are accustomed to expect a more or less severe endemic of catarrhal troubles among horses about the first of October of every year. The horse is very liable to atmospheric influences, far more so than the human species, and the changes in the weather occurring about that time suffice to produce an apparent epidemic of catarrhal troubles among them. In some years few, in others many horses are affected; the present year the number has been so large as to temporarily interfere with business, but this is exceptional.

The disease lasts but a few days, the main trouble is a bronchitis associated with a slight catarrh of the nasal mucus membrane; for a period of from twelve to forty-eight hours there is also a febrile disturbance. The highest temperature recorded by a veterinarian, from an observation of fully one thousand cases has been

$106\frac{1}{2}°$ Fahrenheit. The disorder is not fatal, it hardly requires any treatment even; only in debilitated or very old animals, or such as are overworked by inhuman owners, may fatal complications arise. Few deaths have taken place; a veterinarian in Yorkville who has visited stables containing an aggregate of a thousand affected horses, has had but a single death, that of an animal overdriven while convalescing, and in which pulmonary congestion resulted.

There is as yet no proof that the affection is contageous; it is rather endemic than epidemic. The rapidity with which it has successively appeared in Boston, New York and Chicago, speaks more in favor of an atmospheric cause than of transmission by contagion. A Boston microscopist asserts that bacteria or micrococci are active factors in its transmission, but he makes the statement, rather as an inference, than on the basis of observation. The same veterinarian, to whom we owe the communication of several facts here mentioned, tried to inoculate his own horse with the disease, by introducing the discharged matter from sick horses into its air passages, and failed in this and other experiments of the same kind. It is also observed that the endemic has appeared more frequently and affected more horses in large, well ventilated stables, in which the influence of outside changes in the temperature is quickly felt, than in close and confined quarters where the air is, if more impure, warmer, and the oscillations of the outside temperature less suddenly made manifest than in the former.

As far as this city is concerned, the *acme* of the endemic is past, and owners of horses frightened by sensational reports in the daily papers are recovering their wonted composure. If it has done nothing else the distemper has taught the one lesson, that when a horse is ill, the policy of getting as much work out of him as possible is, not to speak of its barbarity, exceedingly short-sighted, for no vigorous animals have perished in this endemic, except such as those in whose case this "penny wise, pound foolish" idea had been carried out.

PROFESSOR EDWARD C. PICKERING, of Cambridge, describes a novel celestial object observed by him on the 28th of August last, which presented a faint continuous spectrum with a bright band near each end. Clouds interfered, and barely permitted an identification with Oeltzen 17681, or a position in 1880 of R. A., 18h. 1m. 17s.; Dec., 21° 16'.

The object might be mistaken for a temporary star, like that in Corona in 1863, and the bands assumed to correspond to the Hydrogen lines C and F. Professor Pickering appeared to be unable to determine whether it was a nebula, a mass of incandescent gas resembling a nebula in character but not in constitution, or whether it was a star with a vast atmosphere of incandescent gas of a material not as yet known to us. The discovery of this object, in his opinion, greatly increases the difficulty of distinguishing between a star and a planetary nebula.

The observation was made on the 24th of August and described on the 2d of September, but in consequence of the fact that Professor Pickering sent his communication to a foreign journal, three thousand miles away, it was thus the second week in October when it came before the American public.

SCIENCE IN FRANCE AND GERMANY.

Dr. C. K. Akin has written a series of letters from Pesth to Professor G. C. Stokes, Secretary to the Royal Society, who was one of the Royal Commission on Scientific Instruction. These letters are dated 1870, but are now published for the first time by *The Journal of Science*, London.

In what may be called a supplemental communication Dr. Akin describes the condition of the most prominent scientific institutions in France and Germany. His remarks on the system of centralization, and abuse of the authority of those who profess an infallibility in respect to the human mind will be read with interest.

He states that these scientific magnates, the recognized "authority" in Germany, instead of rendering encouragement to students, positively check and impede all progress outside of their own circle, keep out new men with novel ideas as long as possible, so as to hold their own sway.

But we will leave Dr. Akin to make his own statement:

"The French Academy is in some respects similar to the Royal Society, and the points in which it differs from the latter are not, in my opinion, to its advantage. In the first place, the members of the Academy are salaried by the Government, but their emoluments are not sufficient to live upon, or to keep them, so to speak, in working order; nor do they perform any specific service to Science or the State for the money. The Academy, next, is divided into a certain number of sections, according to the several branches of science, and the number of members in each section is strictly limited. As that subdivision is invariable, while the relative importance of the sciences is fluctuating, the abuse has crept in of electing members into a wrong division. On the other hand, such a proceeding not being always practicable, highly distinguished men are excluded from the Academy for many years if their proper sections happen to be full; while if, from the dearth of cultivators or accidents of mortality, the number of vacancies happens to be great, the standard of admission is considerably lowered. The Academy publishes weekly its proceedings or "Comtes Rendus," which, from the celerity and regularity of their publication, are a valuable means of conveying rapid information; on the contrary, its transactions or "Memoires" are issued in a very irregular and dilatory manner. The practice of examining and reporting upon communications submitted has fallen into almost complete disuse; and the prizes, which are in a considerable number, are in a great part awarded upon the antiquated principle of putting forth questions. I have thus rapidly drawn the most distinctive features of the French

Academy, roughly yet faithfully; and I feel constrained to confess my inability to comprehend the enthusiasm which there appears to exist in certain quarters in England for this institution, and which shows itself in the desire to copy it. I have dwelt in a former letter upon the functions which any society should perform in order to be called useful, and I cannot bring myself to believe that those of the French Academy correspond in any way to the model.

I have spoken, in a former communication, in words of unavoidable eulogium, of the German Universities and the position which they occupy among similar institutions in Europe. Still I do not find in their organization anything that I should be prepared to recommend for imitation or adoption. I shall presently mention the mischievous effects which the Universities in Germany, like the Academy in France, exercise on scientific development, according to my belief, when I shall enter upon the discussion of the principles which underlie the organization of both: here I wish merely to give an opinion upon the institution of so-called *privat-docenten*, which is generally considered as most characteristic of the German University system, and which has many admirers out of Germany. A *privat-docent* is simply a lecturer who, as a rule, receives no pay from government or the University, but may take fees from the students: he is simply a private tutor, who, in consideration of having passed an examination or other ordeals before the proper authorities, is admitted to the use of the public lecture-rooms. In my opinion the fellowships in the English Universities—if only Fellows were elected upon a better principle—are much more advantageous; and if the now somewhat dormant institutions of lecturers and prælectors in the colleges were more largely developed, the English Universities would have nothing to envy from, and much to boast over, those of Germany in this respect.

The principal aim of the German Universities, as well as of the French Academy, is to uphold the principle of *authority* in science, which has a great many effects that are detrimental to its progress. Authority in science means infallibility, and it means also stagnation. But the essence of science is development, which is identical with change, and variation from ancient theories or received doctrines. The French Academy has generally not been favorable to novelties started out of its own precincts, as is shown by its treatment of such men as Fresnel, Fourier or Melloni. I know also of a case in which it was found impossible to get a correction or mention of mistakes, which one of its members had happened to make, inserted in the proceedings of the Academy, notwithstanding repeated attempts. The desire to have this done was supposed to imply *naïveté*. In a similar way the German Universities enforce a certain uniformity in the preparation of scientific students, and they measure all ability by a fixed yet arbitrary standard. Investigation must be *schulgerecht*, as it is called—for which the French have the word *classique*, but I doubt whether there be any real equivalent in English. A mind of independent character or original turn has thus a hard struggle for existence; for, in order to get recognized, it must be fashioned on the approved pattern. Men like Davy or Faraday are consequently unknown to the history of German or French science, as their irregular preparation would have debarred them from coming under notice, and still more so from making their way. On the other hand, great errors are propagated and kept up under the wing of authority; and if once a philosopher has obtained a certain sway, or formed a so-called "school," his teaching will be kept up long after its errors have been detected. Thus certain theories are still taught all over Germany in physics which are manifestly untenable, and to attack them is punished more severely than heresy is in religion nowadays. Theories propounded by new men are generally overlooked. On the other hand, I could tell an instance in the recent history of physical science where a discovery undoubtedly not novel and manifestly incomplete has been accepted on the Continent as an unexpected revelation proof against all doubt, because it was appropriated by names possessing authority. What constitutes authority in science it were difficult to define; yet its worship, although it be opposed to the very spirit of science, is in Germany and France, so to speak, without bounds. It were easy to prove by example that the test of infallibility is not applicable, if such a thing could be imagined with respect to a human mind. Not only are the instances numerous where the authorities of one age have been scouted by those of the succeeding, but even in the works of the greatest among them, whose reputations were acquired on the strength of real intellect and conspicuous services, schoolboys nowadays frequently may point out glaring mistakes committed or upheld by great masters only one generation behind.

I have mentioned in a former letter the well-known fact that a German philosopher who wished to bring out some novel theory in his country encountered so many difficulties that he absolutely went mad. Another who started similar ideas about the same time, having been repulsed in one quarter, took it for granted that the same had happened to him also in another, where it was not the case, so hopeless did he consider his endeavor to obtain a hearing. Actually these ideas took wing in England, but not before, communicated also to the French Academy, they had been allowed to rest unnoticed in its archives for years (like the memoirs of Abel), notwithstanding repeated instances to have them examined. I also have it out of the mouth of one, who is actually himself a chief authority on physical science in Germany, that an early work of his, now the principal foundation of his fame, had proved injurious to his university career, for being of too novel a character. It is a slight consolation to the individuals concerned, for the anxiety or pain they have suffered, to have had their names recently enrolled on the list of members of the French Academy, or to have received an honorary title from a German University; and the damage which is done to science by such proceedings, in all cases serious, is in many irreparable. Authority, whether exercised by academies or universities, would have its uses if it facilitated the endeavors of students during the early and more trying periods of their career, in which encouragement and aid are most welcome and needed; but if, instead, it check or impede novices, and establish merely a kind of confraternity, the chief end of which is to keep new men out as long as feasible, and to uphold its own sway, I make bold to say that the liberty of thought reigning in England, notwithstanding its abuses, is a far more valuable safeguard for science, the very life of which is progress. Now, if the Royal Society, transformed into or superseded by an academy, were to arrogate to itself that kind of domination which the Académie des Sciences exercises in France, or if the English universities endeavored to absorb all the intellectual life of the nation, or to fashion it in their own way, as is the case in Germany, the superiority of England, which has made it the head-quarters of scientific progress and the mother country of so many amateurs more distinguished in science than most French academicians or German professors, would probably be gone.

TOXICOLOGY.—An Italian commission, including among its members Prof. Selmi, is examining the methods for the detection of poisonous alkaloids in the viscera, with especial reference to the so called "ptomaines,"—alkaloids which under certain circumstances may be generated during the putrescence of animal matter.

NOTE ON THE ZODIACAL LIGHT.*

By Henry Carwill Lewis.

The results of a series of observations upon the zodiacal light made by the writer, extending over a period of nearly five years, is here recorded. The special precautions taken, both to train the eye to detect faint lights, and to prevent bias on the part of the observer, were given in detail. The zodiacal light may be divided into three portions—the *zodiacal cone*; the *zodiacal band*; and the *gegenschein*. This division is convenient in observation, saves confusion in description, and may be in part a natural one.

The zodiacal cone.—This, the zodiacal light proper, of most authors, is the well-known cone of light rising along the ecliptic, and best seen in the winter months in the West, immediately after the disappearance of twilight. The time of shortest twilight coincides with its greatest brilliancy. Several observations are given when the writer saw it cast a distinct *shadow* at that time. Its comparative brightness with the Via Lactea at different seasons were given, and its relation to the ecliptic discussed. It was stated that the cone in our latitude is not symmetrical; and that while its axis of greatest brightness lies exactly upon the ecliptic, its axis of symmetry is north of that line. An inner short cone of greater brightness was described. The warm color was shown to be due to atmospheric absorption. No pulsations were ever observed which could not be explained either by atmospheric changes or by changes in the eyesight of the observer. No periodic changes in the zodiacal light were observed; the same series of changes occurring each year with an equal amount of brilliancy. It was shown that while the zodiacal cone is frequently seen by moonlight, the moon appears to have no appreciable influence upon it. The account of the zodiacal cone closes with a description of its *spectrum*, which is always continuous and free from bright lines.

The zodiacal band.—This is an extremely faint zone of light, somewhat wider than the Via Lactea, which, like a strip of gauze, is stretched across the sky along the zodiac from horizon to horizon, and which can be seen at all times. It is a belt which forms a very faint prolongation of the zodiacal cone, and which, like it, is best seen when the ecliptic makes a large angle with the horizon. It is so faint that it can only be seen with difficulty. The best method of observing it is described. It is brightest along an inner line, and fades off more suddenly on its southern than on its nothern edge. It has a width of about 12°, and its central line is slightly north of the ecliptic. Observations prove the zodiacal band to be a constant and invariable phenomenon.

The gegenschein.—The gegenschein is a faint patch of light, some 7° in diameter, which nightly appears in that part of the zodiacal band, which is 180° from the sun. Night after night it shifts its place so as to keep opposite to the sun. It is decidedly brighter than the zodiacal band, and occasionally a central nucleus about 2° in diameter, of greater brightness, can be observed. While the brighter portion of the gegenschein is circular, its faint boundaries have sometimes the form of an oval, whose major axis is parallel to the ecliptic. A large number of maps of its position among the stars have been made, which show that while its central point is always 180° in longitude from the sun, it has a latitude of $+ 2°$.

The moon zodiacal light.—An oblique cone of light in the proximity of the moon was described by Rev. G. Jones, but has not been detected by the writer. The light preceding moonrise rises at right angles to the horizon, and seems purely atmospheric. One observer has described comet-like tails on either side of the moon. The writer holds that such appearances are caused by diffraction through floating vapor, since they are never seen on clear nights.

The horizon light.—The phenomenon to which this name is applied, though having no connection with the zodiacal light, is so continually observed with the latter, and at certain seasons is so apt to be confounded with portions of it, that it is necessary to take it into account. The horizon light is a faint band of light with parallel sides, lying all around and parallel to the horizon, and separated from it by an interval of darkness. It is brightest, and terminates most abruptly on its lower edge. This sharp lower edge is 5° above the horizon, while the diffuse upper edge varies in altitude with the state of the atmosphere. The horizon light has a mean width of about 15°. It is purely atmospheric and appears to be caused by reflected starlight. It becomes very bright when the moon is above the horizon. Below the horizon light is a very dark space here called the *absorption band*. This quenches the light of the Via Lactea, the zodiacal cone, and all except the largest stars and planets, which last, while in it, are deeply colored. In the summer, when the ecliptic is low, the horizon light frequently blends with the zodiacal band.

THE ACTION OF SUNLIGHT ON GLASS.*

By Thomas Gaffield.

As great a variety of tints and colors appears after exposure to sunlight as is witnessed in the original specimens. A general classification of the changes of color produced by the sun in colorless glasses is as follows: 1. From white to yellowish. 2. From greenish to yellowish-green. 3. From brownish-yellow and greenish tints to purple. 4. From light-green or greenish-white to bluish. 5. From bluish and other tints to darker tints of the same colors. Every specimen of colorless glass exposed ten years shows some change of color or tint, except some white flint glass, such as is used for fine glassware and optical glass. The optical glasses with the exception of two specimens of crown, which became of a yellowish color, showed only a very slight change of tint, leading some to the opinion that oxide of lead, which enters largely into its composition, may act as a protecting shield against change by sunlight exposure. In experimenting for ten years with colored glasses of the main spectral colors (red, orange, yellow, &c.), no change was observed in any pot-metal specimens (colored throughout the body) save a slight darkening of the purple. A change to a purplish or yellowish color was observed in the colorless body of some of the flashed and stained specimens, when looking through the edges of these glasses, which are originally colored on the surface only. The sunlight coloration is not sufficient to be noticed in an observation through the surface of the glass. An experiment with pot-metals not of the primary colors, but of the intermediate ones which most nearly approach those which are produced in colorless glass by sunlight exposure, showed the following changes: First, from brownish tints to a flesh color; second, from flesh color to tints of violet or purple; third, from amber, olive and purple to darker tints of the same colors.

It is interesting to know that, so far as such colors in pot-metal were used in the old cathedral windows, the results of these experiments prove that they must have changed in color or tint, and that the glass which we see in these old churches to-day, and which has suffered sunlight exposure for centuries, must be of very different hue from that which it exhibited when it left the artist's studios or the glass factories of the mediæval ages. It is a curious fact, noticed by Pelouze and Percy, and confirmed by Mr. Gaffield's experiments, that, with some exceptions among the colored specimens, all of the glasses changed in tint or color by sunlight exposure can be restored to their original color by the heat of a glass-stainer's kiln, and can again be colored after a second exposure to sunlight; and that this coloration by sunlight and de-coloration by heat (of about the temperature of red heat) can be carried on indefinitely. Diffused light will also color glass, but only with a greatly diminished effect, proportioned to its comparison with the power of the direct rays of the sun.

ON A SOLUTION OF FERRIC GALLATE AND FERRIC OXALATE AS A REAGENT FOR THE QUANTITATIVE ANALYSIS OF AMMONIA.*

By Prof. N. B. Webster, of Norfolk, Va.

Preparation.—Ferric sulphate in solution is decomposed by gallic acid, and the resulting black ferric gallate is par-

* Read before the A. A. A. S., Boston.

tially decomposed by oxalic acid till the color is reduced to a bluish-black tinge.

Application.—A suitable quantity of the re-agent, prepared as above, is added to a solution of free ammonia or its carbonate, in the same way that Nessler's solution of mercuric per-iodide is used in Manklyn's well-known process.

Result.—The combination of the ammonia with part or all of the oxalic acid of the colorless ferric oxalate of the re-agent, and the blackening of the solution by the re-formation of ferric gallate.

Estimation of Ammonia.—By an imitation of a standard solution of ammonia with the re-agent, as in Wanklyn's mode of Nesslerizing. When the solution to be tested and the imitation solution correspond in color, it is inferred that they contain equal quantities of ammonia. In this process the standard ammonia test should be made from the *carbonate*, and its strength may be such that one litre shall contain one milligramme of ammonia, or one part in a million. Another and more direct way of estimating ammonia is by adding a standard test solution of oxalic acid to the blackened solution of the re-agent and liquid to be tested, till the original color is produced, and from the known quantity of oxalic acid used to calculate the quantity of ammonia in the resulting oxalate. Chemists will find this re-agent both convenient and sensitive.

THE UNITY OF NATURE.

By the Duke of Argyll.

In the preface to the first edition of the "Reign of Law," published in 1866, the following passage occurs:—"I had intended to conclude with a chapter on Law in Christian Theology. It was natural to reserve for that chapter all direct reference to some of the most fundamental facts of Human Nature. Yet, without such reference, the 'Reign of Law,' especially in the 'Realm of Mind,' cannot even be approached in some of its very highest and most important aspects. For the present, however, I have shrunk from entering upon questions so profound, and of such critical import, and so inseparably connected with religious controversy."

The great subject spoken of in this passage has ever since been present with me. Time, indeed, has only increased my sense of its importance. But the years have also added, perhaps in more than equal proportion, to my sense of its depth and of its difficulty. What has to be done, in the first place, is to establish some method of inquiry, and to find some secure avenue of approach. Before dealing with any part of the Theology which is peculiarly Christian, we must trace the connection between the Reign of Law and the ideas which are fundamental to all religions. It is to this preliminary work that the following chapters have been devoted. Modern Doubt has called in question not only the whole subject of inquiry, but the whole faculties by which it can be pursued. Until these have been tested and examined by some standard which is elementary and acknowledged, we cannot even begin the work.

It has appeared to me that not a few of the problems which lie deepest in that inquiry, and which perplex us most, are soluble in the light of the Unity of Nature. Or if these problems are not entirely soluble in this light, at least they are broken up by it, and are reduced to fewer and simpler elements. The following chapters are an attempt to follow this conception along a few of the innumerable paths which it opens up, and which radiate from it through all the phenomena of the Universe, as from an exhaustless centre of energy and of suggestion.

It is the great advantage of these paths that they are almost infinite in number and equally various in direction, To those who walk in them nothing can ever come amiss. Every subject of interest, every object of wonder, every thought of mystery, every obscure analogy, every strange intimation of likeness in the midst of difference—the whole external and the whole internal world—is the province and the property of him who seeks to see and to understand the Unity of Nature. It is a thought which may be pursued in every calling—in the busiest hours of an active life, and in the calmest moments of rest and of reflection. And if, in the wanderings of our own spirit and in the sins and sorrows of Human Life, there are terrible facts which resist all classification and all analysis, it will be a good result of our endeavors to comprehend the Unity of Nature, should it lead us better to see, and more definitely to understand, that which constitutes The Great Exception.

I commend these chapters to the consideration, and I submit them to the criticism, of those who care for such inquiries. Like the former Work, of which this is a sequel, some parts of it have appeared separately in another form. These have been reconsidered, and to some extent re-written; whilst a new meaning has been given to the reasoning they contain by the place assigned to them in a connected treatise.

The publication of it as a series of Articles, before its final appearance as a volume, will afford me, I hope, the advantage of hearing and of seeing what may be said and written of its errors or of its deficiencies. Perhaps, also, it may afford me an opportunity, before the whole of these Articles have appeared, of writing at least one more chapter on an important subject, for which leisure fails me now.

I.

GENERAL DEFINITIONS AND ILLUSTRATIONS OF THE UNITY OF NATURE—WHAT IT IS, AND WHAT IT IS NOT.

The system of Nature in which we live impresses itself on the mind as one system. It is under this impression that we speak of it as the Universe. It was under the same impression, but with a conception specially vivid of its order and its beauty, that the Greeks called it the Kosmos. By such words as these, we mean that Nature is one whole —a whole of which all the parts are inseparably united—joined together by the most curious and intimate relations, which it is the highest work of observation to trace, and of reason to understand.

I do not suppose that there is any need of proving this—of proving, I mean, that this is the general impression which Nature makes upon us. It may be well, however, to trace this impression to its source—to see how far it is founded on definite facts, and how far it is strengthened by such new discoveries as science has lately added to the knowledge of mankind.

One thing is certain: that whatever science may have done, or may be doing, to confirm man's idea of the unity of Nature, science, in the modern acceptation of the term, did not give rise to it. The idea had arisen long before science in this sense was born. That is to say, the idea existed before the acquisition of physical knowledge had been raised to the dignity of a pursuit, and before the method and the results of that pursuit had been reduced to system. Theology, no doubt, had more to do with it. The idea of the unity of Nature must be at least as old as the idea of one God; and even those who believe in the derivation of Man from the savage and the brute, cannot tell us how soon the Manotheistic doctrine arose. The Jewish literature and traditions, which are at least among the oldest in the world, exhibit this doctrine of the purest form, and represent it as the doctrine of primeval times. The earliest indications of religious thought among the Aryan races point in the same direction. The records of that mysterious civilization which had been established on the Nile at a date long anterior to the call of Abraham, are more and more clearly yielding results in harmony with the tradition of the Jews. The Polytheism of Egypt is being traced and tracked through the ready paths which led to the fashioning of many Gods out of the attributes of One.[1] Probably those who do not accept this conclusion as historically proved may hold rather that the idea of the unity of Nature preceded the idea of the unity of God, and that Monotheism is but the form in which that earlier idea became embodied. It matters not, so far as my present purpose is concerned, which of these two has been the real order of events. If the law prevailing in the infancy of our race has been at all like the law prevailing in the infancy of the individual, then Man's first beliefs were derived from authority, and not from either reasoning or observation. I do not myself believe that in the morning of the world The-

[1] Renouf, "Hibbert Lectures," 1879. p. 89.

ism arose as the result of philosophical speculation, or as the result of imagination personifying the unity of external Nature. But if this were possible, then it would follow that while a perception of the unity or the unity of Nature must be at least as old as the idea of one Creator, it may be a good deal older. Whether the two ideas were ever actually separated in history, it is certain that they can be, and are, separated at the present time. A sense and a perception of the unity of Nature—strong, imaginative, and almost mystic in its character—is now prevalent among men over whom the idea of the personal agency of a living God has, to say the least, a much weaker hold.

What, then, is this unity of Nature? Is it a fact or an imagination? Is it a reality or a dream? Is it a mere poetic fancy incapable of definition; or is it a conception firmly and legitimately founded on the phenomena of the world.

But there is another question which comes before these. What do we mean by unity? In what sense can we say that an infinite number and a variety of things are nevertheless one? This is an important question, because it is very possible to look for the unity of Nature in such a manner that, instead of extending our knowledge, or rendering it more clear and definite, we may rather narrow it, and render it more confused. It has been said that all knowledge consists in the mere perception of difference. This is not accurate: but it is true that the perception of difference is the necessary foundation of all knowledge. For if it be possible to give any short definition of that in which essentially all knowledge consists, perhaps the nearest approach to such a definition would be this: that knowledge is the perception of relations. To know a thing and to understand it, is to know it in its relation to other things. But the first step in this knowledge is to know it as distinguished from other things. The perception of difference comes before the perception of all other and higher relations. It is well, therefore, to remember that no increase of knowledge can be acquired by a willful forgetfulness of distinctions. We may choose to call two things one, because we choose to look at them in one respect only, and to disregard them in other respects quite as obvious, and perhaps much more important. And thus we may create a unity which is purely artificial, or which represents nothing but a comparatively insignificant incident in the system of Nature. For as things may be related to each other in an infinite variety of ways—in form, or in size, or in substance, or in position, or in modes of origin, or in laws of growth, or in work and function—so there are an infinite number and variety of aspects in which unity can be traced. And these aspects rise in an ascending series according to the completeness of our knowledge of things, and according to the development of those intellectual faculties by which alone the higher relations between them can be perceived. For the perception of every relation, even that of mere physical continuity, is purely the work of mind, and this work can only be performed in proportion to the materials which are supplied, and to the power of interpretation which is enjoyed. It is very easy to rest satisfied with the perception of the commoner and more obvious relations of things to each other, and even to be so engrossed with these as to be rendered altogether incapable of perceiving the finer and less palpable relations which constitute the higher unities of Nature. New relations, too, by no means obvious, but discovered by analysis, may, from the mere effect of novelty, engross attention far beyond their real importance. Nay, more—it may be said, with truth, that this is a danger which, for a time at least, increases with the progress of science, because it must obviously beset special subjects of inquiry and special methods of research. The division of labor necessarily becomes more and more minute with the complication of the work which is to be done, and branches out into a thousand channels of inquiry, each of which finds its natural termination in the ascertainment of a special series of relations. The chemist is engaged with the elementary combinations of matter, and finds a unity of composition among things which in all other aspects are totally diverse. The anatomist is concerned with structure, and separates widely between things which may nevertheless be identical in chemical composition. The physiologist is concerned with function; and, finding the same offices performed by a vast variety of structures, ranges them across all their differences under a single name. The comparative anatomist is concerned with the relative place or position of the parts in organic structures; and, although he finds the same part in different creatures performing widely different functions, he nevertheless pronounces them to be the same, and to be one in the homologies of an ideal archetype. But each of these inquirers may be satisfied with the particular unity which his own investigations lead him specially to observe, and may be blind altogether to the unity which is next above it. And so it may well be that the sense of unity in Nature, which Man has had from very early times, reflected in such words as the "Universe," and in his belief in one God, is a higher and fuller perception of the truth than is commonly attained by those who are engrossed by the laborious investigation of details. This is one of the many cases in which the intuitions of the mind have preceded inquiry, and gone in advance of science, leaving nothing for systematic investigation to do, except to confirm, by formal proofs, that which has been already long felt and known.

I have already indicated the sense in which the unity of Nature impresses itself on the intelligence of Man. It is in that intricate dependence of all things upon each other which makes them appear to be parts of one system. And even where the connection falls short of dependence, or of any visible relation, the same impression of unity is conveyed in the prevalence of close and curious analogies which are not the less striking when the cause or the reason of them is unknown.

I propose in this chapter to specify some of the signs of unity which the study of Nature has more definitely revealed, and consider how far they carry us.

There is one sign of unity which, of itself, carries us very far indeed. It is the sign given to us in the ties by which this world of ours is bound to the other worlds around it. There is no room for fancy here. The truths which have been reached in this matter have been reached by the paths of rigorous demonstration. This earth is part of the vast mechanism of the heavens. The force, or forces, by which that mechanism is governed are forces which prevail not only in our own solar system, but, as there is reason to believe, through all Space, and are determining, as astronomers tell us, the movement of our sun, with all its planets, round some distant centre, of which we know neither the nature nor the place. Moreover, these same forces are equally prevailing on the surface of this earth itself. The whole of its physical phenomena are subject to the conditions which they impose.

If there were no other indications of unity than this, it would be almost enough. For the unity which is implied in the mechanism of the heavens is indeed a unity which is all-embracing and complete. The structure of our own bodies, with all that depends upon it, is a structure governed by, and therefore adapted to, the same force of gravitation which has determined the form and the movement of myraids of worlds. Every part of the human organism is fitted to conditions which would all be destroyed in a moment if the forces of gravitation were to change or fail. It is, indeed, evident that a force such as this must govern the whole order of things in which it exists at all. Every other force must work, or be worked, in subordination to it.

Nor is gravitation the only agency which brings home to us the unity of the conditions which prevail among the worlds. There is another: Light—that sweet and heavenly messenger which comes to us from the depths of Space, telling us all we know of other worlds, and giving us all that we enjoy of life and beauty on our own. And there is one condition of unity revealed by Light which is not revealed by gravitation. For, in respect to gravitation, although we have an idea of the *measure*, we have no idea of the *method*, of its operation. We know with precision the numerical rules which it obeys, but we know nothing whatever of the way in which its work is done. But in respect to Light, we have an idea not only of the measure, but of the mode of its operation. In one sense, of course, Light is a mere sensation in ourselves. But when we speak of it as an external thing, we speak of the cause of that sensation. In this sense, Light is a wave or an undulatory vibration, and such vibrations can only be propagated in a medium which, however thin, must be material. Light, therefore, reveals to us the fact that we are united with the most distant

worlds, and with all intervening space, by some ethereal atmosphere, which embraces and holds them all. Moreover, the enormous velocity with which the vibrations of this atmosphere are propagated proves that it is a substance of the closest continuity, and of the highest tension. The tremors which are imparted to it by luminous bodies rush from particle to particle at the rate of 186,000 miles in a second of time ; and thus, although it is impalpable, intangible, and imponderable, we know that it is a medium infinitely more compact than the most solid substance which can be felt and weighed. It is very difficult to conceive this, because the waves or tremors which constitute Light are not recognizable by any sense but one : and the impressions of that sense give us no direct information on the nature of the medium by which those impressions are produced. We cannot see the luminiferous medium except when it is in motion, and not even then, unless that motion be in a certain direction toward ourselves. When this medium is at rest we are in utter darkness, and so are we also when its movements are rushing past us, but do not touch us. The luminiferous medium is, therefore, in itself, invisible ; and its nature can only be arrived at by pure reasoning—reasoning, of course, founded on observation, but observation of rare phenomena, or of phenomena which can only be seen under those conditions which Man has invented for analyzing the operations of his own most glorious sense. And never, perhaps, has Man's inventive genius been more signally displayed than in the long series of investigations which first led up to the conception, and have now furnished the proof, that Light is nothing but the undulatory movement of a substantial medium. It is very difficult to express in language the ideas upon the nature of that medium which have been built up from the facts of its behavior. It is difficult to do so, because all the words by which we express the properties of Matter refer to its more obvious phenomena —that is to say, to the direct impressions which Matter makes upon the senses. And so, when we have to deal with forms of Matter which do not make any impressions of the same kind—forms of matter which can neither be seen, nor felt, nor handled, which have neither weight, nor taste, nor smell, nor aspect—we can only describe them by the help of analogies as near as we can find. But as regards the qualities of the medium which causes the sensation of Light, the nearest analogies are remote, and what is worse, they compel us to associate ideas which elsewhere are so dissevered as to appear almost exclusive of each other. It is now more than half a century since Dr. Thomas Young astonished and amused the scientific world by declaring of the luminiferous medium that we must conceive of it as finding its way through all Matter as freely as the air moves through a grove of trees. This suggests the idea of an element of extreme tenuity. But that element cannot be said to be thin in which a wave is transmitted with the enormous velocity of Light. On the contrary, its molecules must be in closest contact with each other when a tremor is carried by them through a thickness of 186,000 miles in a single second. Accordingly, Sir J. Herschel has declared that the luminiferous ether must be conceived of not as an air, nor as a fluid, but rather as a solid—"in this sense at least, that its particles cannot be supposed as capable of interchanging places, or of bodily transfer to any measurable distance from their own special and assigned localities in the universe."[2] Well may Sir J. Herschel add that "this will go far to realize (in however unexpected a form) the ancient idea of a chrystalline orb." and thus the wonderful result of all investigation is that this earth is in actual rigid contact with the most distant worlds in space—in rigid contact, that is to say, through a medium which touches and envelops all, and which is incessantly communicating from one world to another the minutest vibrations it receives.

The laws, therefore, and the constitution of Light, even more than the law of gravitation, carry up to the highest degree of certainty our conception of the Universe as one ;— one, that is to say, in virtue of the closest mechanical connection, and of the prevalence of one universal medium.

Moreover, it is now known that this medium is the vehicle not only of Light but also of Heat, whilst it has likewise a special power of setting up, or of setting free, the mysterious action of chemical affinity. The beautiful experiments have become familiar by which these three kinds of ethereal motion can be separated from each other in the solar spectrum, and each of them can be made to exhibit its peculiar effects. With these again the forces of galvanism and electricity have some very intimate connection, which goes far to indicate like methods of operation in some prevailing element. Considering how all the forms of Matter, both in the organic and in the inorganic worlds, depend on one or other, or on all of these—considering how Life itself depends upon them, and how it flickers or expires according as they are present in due proportion—it is impossible not to feel that in this great group of powers, so closely bound up together, we are standing very close indeed to some pervading, if not universal, agency in the mechanism of Nature.

This close connection of so many various phenomena with different kinds of movement in a single medium is by far the most striking and instructive discovery of modern science. It supplies to some extent a solid physical basis, and one veritable cause, for part, at least, of the general impression of unity which the aspects of Nature leave upon the mind. For all work done by the same implement generally carries the mark of that implement, as it were of a tool, upon it. Things made of the same material, whatever they may be, are sure to be like in those characteristics which result from identical or from similar properties and modes of action. And so far, therefore, it is easy to understand the constant and close analogies which prevail in that vast circle of phenomena which are connected with Heat, Light, Electricity, Chemical and Vital Action.

But although the employment of one and the same agency in the production of a variety of effects is, no doubt, one cause of the visible unity which prevails in Nature, it is not the only cause. The same close analogies exist where no such identity of agency can be traced. Thus the mode in which the atmosphere carries Sound is closely analogous to to the mode in which the ether carries light. But the ether and the atmosphere are two very different agents, and the similarity of the laws which the undulations of both obey is due to some other and some more general cause of unity than identity of material. This more general cause is to be found, no doubt, in one common law which determines the forms of motion in all Matter, and especially in highly elastic media.

But, indeed, the mere physical unity which consists in the action of one great vehicle of power, even if this were more universally prevalent than it is known to be, is but the lowest step in the long ascent which carries us up to a unity of a more perfect kind. The means by which some one single implement can be made to work a thousand different effects, not only without interference, and without confusion, but with such relations between it and other agents as to lead to complete harmonies of result, are means which point to some unity behind and above the implement itself—that is to say, they point to some unity in the method of its handling, in the management of the impulses which, receiving, it conveys, and in the arrangement of the materials on which it operates.

No illustration can be given of this higher kind of unity which is half so striking as the illustration which is afforded by the astonishing facts now familiar as to the composition of solar light. When we consider that every color in the spectrum represents the motion of a separate wave or ripple, and that in addition to the visible series there are other series, one at each end of the luminous rays, which are non-luminous, and therefore invisible—all of which consist of waves equally distinct ; when we consider farther that all these are carried simultaneously with the same speed across millions of miles ; that they are separable, and yet are never separated ; that they are more accurately together, without jostling or confusion, in perfect combination, yet so that each shall be capable of producing its own separate effect—it altogether transcends our faculties of imagination to conceive how movements of such infinite complication can be united in one such perfect order.

And be it observed that the difficulty of conceiving this is not diminished, but increased, by the fact that these movements are propagated in a single medium ; because it is most difficult to conceive how the particles of the medium can be so arranged as to be capable of conveying so many different kinds of motion with equal velocities and at the

"2 Familiar Lectures on Scientific Subjects," p. 285.

same instant of time. It is clear that the unity of effect which is achieved out of this immense variety of movements is a unity which lies altogether behind the mere unity of material, and is traceable to some one order of arrangement under which the original impulses are conveyed. We know that in respect to the waves of Sound, the production of perfect harmonies among them can only be attained by a skillful adjustment of the instruments, whose vibrations are the cause and the measure of the aerial waves which, in their combination, constitute perfect music. And so, in like manner, we may be sure that the harmonies of Heat, Light, and Chemical Action, effected as they are amongst an infinite number and variety of motions, very easily capable of separation and disturbance, must be the result of some close adjustment between the constituent element of the conveying medium and the constituent elements of the luminous bodies, whose complex, but joint, vibrations constitute that embodied harmony which we know as Light. Moreover, as this adjustment must be close and intimate between the properties of the ether and the nature of the bodies whose vibrations it repeats, so also must the same adjustment be equally close between these vibrations and the properties of Matter on which they exert such a powerful influence. And when we consider the number and the nature of the things which this adjustment must include, we can, perhaps, form some idea what a bond and bridge it is between the most stupendous phenomena of the heavens and the minutest phenomena of earth. For this adjustment must be perfect between these several things—first, the flaming elements in the sun which communicate the different vibrations in definite proportion; next, the constitution of the medium, which is capable of conveying them without division, confusion, or obstruction; next, the constitution of our own atmosphere, so that neither shall it distort, nor confuse, nor quench the waves; and, lastly, the constitution of those forms of Matter upon earth which respond, each after its own laws, to the stimulus it is so made as to receive from the heating, lighting, and actinic waves.

In contemplating this vast system of adjustment, it is important to analyze and define, so far as we can, the impression of unity which it makes upon us, because the real scope and source of this impression may very easily be mistaken. It has been already pointed out that we can only see likeness by first seeing difference, and that the full perception of that in which things are unlike is essential to an accurate appreciation of that in which they are the same. The classifying instinct must be strong in the human mind, from the delight it finds in reducing diverse things to some one common definition. And this instinct is founded on the power of setting differences aside, and of fixing our attention on some selected conditions of resemblance. But we must remember that it depends on our width and depth of vision whether the unities which we thus select in Nature are the smallest and the most incidental, or whether they are the largest and the most significant. And, indeed, for some temporary purposes—as, for example, to make clear to our minds the exact nature of the facts which science may have ascertained—it may be necessary to classify together, as coming under one and the same category, things as different from each other as light from darkness. Nor is this any extreme or imaginary case. It is a case actually exemplified in a lecture by Professor Tyndall, which is entitled "The Identity of Light and Heat." Yet those who have attended the expositions of that eminent physical philosopher must be familiar with the beautiful experiments which show how distinct in another aspect are Light and Heat; how easily and how perfectly they can be separated from each other; how certain substances obstruct the one and let through the other; and how the fiercest heat can be raging in the profoundest darkness. Nevertheless, there is more than one mental aspect, there is more than one method of conception, in terms of which these two separable powers can be brought under one description. Light and Heat, however different in their effects—however distinct and separable from each other—can both be regarded as "forms of motion" among the particles of Matter. Moreover, it can be shown that both are conveyed or caused by waves, or undulatory vibrations in one and the same ethereal medium. And the same definition applies to the chemical rays, which again are separable and distinct from the rays both of Light and Heat.

But although this definition may be correct as far it goes, it is a definition nevertheless which slurs over and keeps out of sight distinctions of a fundamental character. In the first place, it takes no notice of the absolute distinction between Light or Heat considered as sensations of our organism, or as states of consciousness, and Light or Heat considered as the external agencies which produce these sensations in us. Sir W. Grove has expressed a doubt whether it is legitimate to apply the word "Light" at all to any rays which do not excite the sense of vision. This, however, is not the distinction to which I now refer. If it be an ascertained fact, or if it be the only view consistent with our present knowledge, that the ethereal pulsations which do, and those which do not, excite in us the sense of vision, are pulsations exactly of the same kind and in exactly the same medium, and that they differ in nothing but in periods of time or length of wave, so that our seeing of them or our not seeing of them depends on nothing but the focusing, as it were, of our eyes, then the inclusion of them under the same word Light involves no confusion of thought. We should confound no distinction of importance, for example, by applying the same name to grains of sand which are large enough to be visible, and to those which are so minute as to be wholly invisible even to the microscope. And if a distinction of this nature—a mere distinction of size, or of velocity, or of form of motion, were the only distinction between light and heat—it might be legitimate to consider them as identical, and to call them by the same name. But the truth is there are distinctions between them of quite another kind. Light, in the abstract conception of it, consists in undulatory vibrations in the pure ether, and in these alone. They may or may not be visible—that is to say, they may or may not be within the range of our organs of vision, just as a sound may or may not be too faint and low, or too fine and high, to be audible to our ears. But the word "heat" carries quite a different meaning, and the conception it conveys could not be covered under the same definition as that which covers light. Heat is inseparably associated in our minds with, and does essentially consist in, certain motions, not of pure ether, but of the molecules of solid or ponderable matter. These motions in solid or ponderable matter are not in any sense identical with the undulatory motions of pure ether which constitute light; consequently when physicists find themselves under the necessity of defining more closely what they meant by the identity of heat and light, they are obliged to separate between two different kinds of heat—that is to say, between two wholly different things, both covered under the common name of heat—one of which is really identical in kind with light, and the other of which is not. "Radiant" heat is the kind, and the only kind of heat, which comes under the common definition. "Radiant" heat consists in the undulatory vibrations of pure ether which are set up or caused by those other vibrations in solid substances or ponderable matter, which are heat more properly so called. Hot bodies communicate to the surrounding ethereal medium vibrations of the same kind with light, some of these being, and others not being, luminous to our eyes. Thus we see that the unity or close relationship which exists between heat and light is not a unity of sameness or identity, but a unity which depends upon and consists in correspondences between things in themselves different. It has been suggested that the facts of nature would be much more clearly represented in language if the old word "Caloric" were revived, in order to distinguish one of the two very different things which are now confounded under the common term "Heat"—tha is to say, heat considered as molecular vibration in solid or ponderable matter. and heat considered as the undulatory vibrations of pure ether which constitute the "heat" called "radiant." Adopting this suggestion, the relations between light and heat, as these relations are now known to science, may be thrown into the following propositions, which are framed for the purpose of exhibiting distinctions not commonly kept in view:

I. Certain undulatory vibrations in pure ether alone are light ether (1) visible, or (2) invisible.

II. These undulatory vibrations in pure ether alone not Caloric.

III. No motions of any kind in pure ether alone are Caloric.

IV. Caloric consists in certain vibratory motions in the molecules of ponderable matter or substances grosser than the ether, and these motions are not undulatory.

V. The motions in ponderable matter which constitute Caloric set up or propagate in pure ether the undulatory vibrations which constitute light.

VI. Conversely the undulatory vibrations in pure ether which constitutes Light set up or propagate in grosser matter the motions which are Caloric.

VII. But the motions in pure ether which are Light cannot set up or propagate in all ponderable matter equally the motions which are Caloric. Transparent substances allow the ethereal undulations to pass through them with very little Caloric motion being set up thereby; and if there were any substance perfectly transparent, no Caloric motion would be produced at all.

VIII. Caloric motions in ponderable matter can be and are set up or propagated by other agencies than the undulations of ether, as by friction, percussion, &c.

IX. Caloric, therefore, differs from Light in being (1) motion in a different medium or in a different kind of matter; (2) in being a different kind of motion; (3) in being producible without, so far as known, the agency of Light at all. I say "so far as known," because as the luminiferous ether is ubiquitous, or as, at least, its absence cannot anywhere be assumed, it is possible that in the calorific effects of percussion, friction, &c., undulations of the ether may be always an essential condition of the production of Caloric.

It follows from these propositions that there are essential distinctions between Light and Heat, and that the effect of luminiferous undulations or "Radiant" Heat in producing Caloric in ponderable matter depends entirely upon, and varies greatly in accordance with, the constitution or structure of the substances through which it passes, or upon which it plays.

The same fundamental distinction applies to those ethereal undulations which produce the effects called Chemical. No such effects can be produced upon substances except according to their special structure and properties. Their effect, for example, upon living matter is absolutely different from the effect they produce upon matter which does not possess vitality. The forces which give rise to chemical affinity are wholly unknown. And so are those which give rise to the peculiar phenomena of living matter. The rays which are called Chemical may have no other part in the result than that of setting free the molecules to be acted upon by the distinct and separate forces which are the real sources of chemical affinity.

What, then, have we gained when we have grouped together, under one common definition, such a variety of movements and such a variety of corresponding effects? This is not the kind of unity which we see and feel in the vast system of adjustments between the sun, the medium conveying its vibrations, and the effect of these on all the phenomena of earth. The kind of unity which is impressed upon us is neither that of a mere unity of material, nor of identity in the forms of motion. On the contrary, this kind of unity among things so diverse in all other aspects is a bare intellectual apprehension, only reached as the result of difficult research, and standing in no natural connection with our ordinary apprehension of physical truth. For our conception of the energies with which we have to deal in Nature must be molded on our knowledge of what they do, far more than on any abstract definition of what they are; or rather, perhaps, it would be more correct to say that our conception of what things are can only be complete in proportion as we take into our view the effects which they produce upon other things around them, and especially upon ourselves, through the organs by which we are in contact with the external world. If in these effects any two agencies are not the same—if they are not even alike—if, perhaps, they are the very antithesis of each other—then the classification which identifies them, however correct it may be, as far as it goes, must omit some characteristics which are much more essential than those which it includes. The most hideous discords which can assail the ear, and the divinest strains of heavenly music, can be regarded as identical in being both a series of sonorous waves. But the thought, the preparation, the concerted design—in short, the unity of mind and of sentiment, on which the production of musical harmony depends, and which it again conveys with matchless power of expression to other minds—all this higher unity is concealed and lost if we do not rise above the mere mechanical definition under which discords and harmonies can nevertheless be in this way correctly classed together. And yet so pleased are we with discoveries of this kind, which reduce, under a common method of conception, things which we have been accustomed to regard as widely different, that we are apt to be filled with conceit about such definitions, as if we had reached in them some great ultimate truth on the nature of things, and as if the old aspects in which we had been accustomed to regard them were by comparison almost deceptive; whereas, in reality, the higher truth may well have been that which we have always known, and the lower truth that which we have recently discovered. The knowledge that Light and Heat are separable, that they do not always accompany each other, is a truer and juster conception of the relation in which they stand to us, and to all that we see around us, than the knowledge that they are both the same in respect of their being both "modes of motion." To know the work which a machine does is a fuller and higher knowledge than to know the nature of the materials of which its parts are composed, or even to perceive and follow the kind of movement by which its effects are produced. And if there be two machines which, in respect to structure and movement and material, are the same, or closely similar, but which, nevertheless, produce totally different kinds of work, we may be sure that this difference is the most real and the most important truth respecting them. The new aspects in which we see their likeness are less full and less adequate than the old familiar aspects in which we regard them as dissimilar.

But the mind is apt to be enamored of a new conception of this kind, and to mistake its place and its relative importance in the sphere of knowledge. It is in this way, and in this way only, that we can account for the tendency among some scientific men to exaggerate beyond all bounds the significance of the abstract definitions which they reach by neglecting differences of work, of function, and of result, and by fixing their attention mainly on some newly discovered likeness in respect to form, or motion, or chemical composition. It is thus that because a particular substance called "Protoplasm" is found to be present in all living organisms, an endeavor follows to get rid of Life as a separate conception, and to reduce it to the physical property of this material. The fallacy involved in this endeavor needs no other exposure than the fact that, as the appearance and the composition of this material is the same whether it be dead or living, the Protoplasm of which such transcendental properties are affirmed has always to be described as "living" protoplasm. But no light can be thrown upon the facts by telling us that life is a property of that which lives. The expression for this substance which has been invented by Professor Huxley is a better one—the "Physical Basis of Life." It is better because it does not suggest the idea that Life is a mere physical property of the substance. But it is, after all, a metaphor which does not give an adequate idea of the conceptions which the phenomena suggest. The word "basis" has a distinct reference to a mechanical support, or to the principal substance in a chemical combination. At the best, too, there is but a distant and metaphorical analogy between these conceptions and the conceptions which are suggested by the connection between Protoplasm and Life. We cannot suppose Life to be a substance supported by another. Neither can we suppose it to be like a chemical element in combination with another. It seems rather like a force or energy which first works up the inorganic materials into the form of protoplasm, and then continues to exert itself through that combination when achieved. We call this kind of energy by a special name, for the best of all reasons, that it has special effects, different from all others. It often happens that the philosophy expressed in some common form of speech is deep and true, whilst the objections which are made to it in the name of science are shallow and fallacious. This is the case with all those phrases and expressions which imply that Life and its phenomena are so distinguishable from other things that they must be spoken of by themselves. The

objection made by a well-known writer,[3] that we might as well speak of "a watch force" as of "a vital force," is an objection which has no validity, and is chargeable with the great vice of confounding one of the clearest distinctions which exist in Nature. The rule which should govern language is very plain. Every phenomenon or group of phenomena which is clearly separate from all others, should have a name as separate and distinctive as itself. The absurdity of speaking of a "watch force" lies in this—that the force by which a watch goes is not separable from the force by which many other mechanical movements are effected. It is a force which is otherwise well-known and can be fully expressed in other and more definite terms. That force is simply the elasticity of a coiled spring. But the phenomena of Life are not due to any force which can be fully and definitely expressed in other terms. It is not purely chemical, nor purely mechanical, nor purely electrical, nor reducible to any other more simple and elementary conception. The popular use, therefore, which keeps up separate words and phrases by which to describe and designate the phenomena of Life, is a use which is correct and thoroughly expressive of the truth. There is nothing more fallacious in philosophy than the endeavor by mere tricks of language, to suppress and keep out of sight the distinctions which Nature proclaims with a loud voice.

It is thus, also, that because certain creatures widely separate in the scale of being may be traced back to some embryonic stage, in which they are undistinguishable, it has become fashionable to sink the vast differences which must lie hid under this uniformity of aspect and of material composition under some vague form of words in which the mind makes, as it were, a covenant with itself not to think of such differences as are latent and invisible, however important we know them to be by the differences of result to which they lead. Thus it is common now to speak of things widely separated in rank and functions being the same, only "differentiated," or "variously conditioned." In these, and in all similar cases, the differences which are unseen, or which, if seen are set aside, are often of infinitely greater importance than the similarities which are selected as the characteristics chiefly worthy of regard. If, for example, in the albumen of an egg there be no discernible differences either of structure or of chemical composition, but if, nevertheless, by a mere application of a little heat, part of it is "differentiated" into blood, another part of it into flesh, another part of it into bone, another part of it into feathers, and the whole into one perfect organic structure, it is clear that any purely chemical definition of this albumen, or any purely mechanical definition of it, would not merely fail of being complete, but would absolutely pass by and pass over the one essential characteristic of vitality which makes it what it is, and determines what it is to be in the system of Nature.

Let us always remember that the more perfect may be the apparent identity between two things which afterwards become widely different, the greater must be the power and value of those invisible distinctions—of those unseen factors—which determine the subsequent divergence. These distinctions are invisible, not merely because our methods of analysis are too coarse to detect them, but because apparently they are of a nature which no physical dissection and no chemical analysis could possibly reveal. Some scientific men are fond of speaking and thinking of these invisible factors as distinctions due to differences in "molecular arrangement," as if the more secret agencies of Nature gave us the idea of depending on nothing else than mechanical arrangement—on differences in the shape or in the position of the molecules of matter. But this is by no means true. No doubt there are such differences—as far beyond the reach of the miscroscope as the differences which the microscope does reveal are beyond the reach of our unaided vision. But we know enough of the different agencies which must lie hid in things apparently the same to be sure that the divergences of work which these agencies produce do not depend upon, or consist in, mere differences of mechanical arrangement. We know enough of those agencies to be sure that they are agencies which do, indeed, determine both arrangement and composition, but do not themselves consist in either.

This is the conclusion to which we are brought by facts which are well known. There are structures in Nature which can be seen in the process of construction. There are conditions of matter in which its particles can be seen rushing under the impulse of invisible forces to take their appointed place in the form which to them is a law. Such are the facts visible in the processes of crystallization. In them we can see the particles of matter passing from one "molecular condition" to another; and it is impossible that this passage can be ascribed either to the old arrangement which is broken up, or to the new arrangement which is substituted in its stead. Both structures have been built up out of elementary materials by some constructive agency which is the master and not the servant—the cause and not the consequence of the movements which are effected, and of the arrangement which is their result. And if this be true of crystalline forms in the mineral kingdom, much more is it true of organic forms in the animal kingdom. Crystals are, as it were, the beginnings of Nature's architecture, her lowest and simplest forms of building. But the most complex crystalline forms which exist—and many of them are singularly complex and beautiful—are simplicity itself compared with the very lowest organism which is endowed with Life. In them, therefore, still more than in the formation of crystals, the work of "differentiation"—that is to say, the work of forming out of one material different structures for the discharge of different functions—is the work of agencies which are invisible and unknown; and it is in these agencies, not in the molecular arrangements which they cause, that the essential character and individuality of every organism consists. Accordingly in the development of seeds and of eggs, which are the germs of plants and animals respectively, the particles of matter can be traced moving, in obedience to forces which are unforseen, from "molecular conditions" which appear to be those of almost complete homogeneity to other molecular conditions which are of inconceivable complexity. In that mystery of all mysteries, of which physicists talk so glibly, the living "nucleated cell," the great work of creation may be seen in actual operation, not caused by "molecular condition," but determining it, and, from elements which to all our senses, and to all our means of investigation, appear absolutely the same, building up the molecules of Protoplasm, now into a sea-weed, now into a cedar of Lebanon, now into an insect, now into a fish, now into a reptile, now into a bird, now into a man. And in proportion as the molecules of matter do not seem to be the masters but the servants here, so do the forces which dispose of them stand out separate and supreme. In every germ this development can only be "after its kind." The molecules must obey; but no mere wayward or capricious order can be given to them. The formative energies seem to be as much under command as the materials upon which they work. For, invisible, intangible, and imponderable as these forces are—unknown and even inconceivable as they must be in their ultimate nature—enough can be traced of their working to assure that they are all closely related to each other, and belong to a system which is one. Out of the chemical elements of Nature, in numerous but definite combinations, it is the special function of vegetable life to lay the foundations of organic mechanism; whilst it is the special function of animal life to take in the materials thus supplied, and to build them up into the highest and most complicated stuctures. This involves a vast cycle of operations, as to the unity of which we cannot be mistaken—for it is a cycle of operations obviously depending on adjustments among all the forces both of solar and terrestrial physics—and every part of this vast series of adjustments must be in continuous and unbroken correlation with the rest.

Thus every step in the progress of science which tends to reduce all organisms to one and the same set of elementary substances, or to one and the same initial structure, only adds to the certainty with which we conclude that it is upon something else than composition, and upon something else than structure, that those vast differences ultimately depend which separate so widely between living things in rank, in function and in power. And although we cannot tell what that something is—although science does not as yet even

[3] Mr. G. H. Lewes.

tend to explain what the directive agencies are or how they work—one thing, at least, is plain: that if a very few elementary substances can enter into an untold variety of combinations, and by virtue of this variety can be made to play a vast variety of parts, this result can only be attained by a system of mutual adjustments as immense as the variety it produces, as minute as the differences on which it depends, and as centralized in direction as the order and harmony of its results. And so we come to understand that the unity which we see in Nature is that kind of unity which the mind recognizes as the result of operations similar to its own—not a unity which consists in sameness of material, or in identity of composition, or in uniformity of structure, but a unity which consists in similar principles of action—that is to say, in like methods of subordinating a few elementary forces to the discharge of special functions, and to the production, by adjustment, of one harmonious whole.

And of this unity, we who see it, and think of it, and speak of it—we are part. In body and in mind we belong to it, and are included in it. It is more easy to admit this as a general proposition than really to see it as truth and to accept all the consequences it involves. The habitual attitude of our thoughts is certainly not in accordance with it. We look on "Nature" as something outside of us—something on which we can look down, or to which we can look up, according to our mood; but in any case, something in which we are exceptions, and which we can and ought to regard from an external point of view. It may be well, therefore, to consider a little more carefully "Man's place in Nature"—his share and position in that unity which he sees and feels around him.

AN IMPROVED MICROTOME.

By Wm. Hailes, M.D., Professor of Histology and Path. Anat., Albany Medical College.

This instrument is designed especially for use in the working laboratories of our medical schools and colleges, where large numbers of sections are required for microscopical examination.

It may be employed as a simple instrument or as a freezing microtome, arranged for ice and salt—ether spray, rhigoline, etc., etc.

The employment of ice and salt (coarse) is preferred, because it costs but little and freezes the mass solidly and quickly, and, if desired, 500 or 1000 sections can be obtained in a few moments' time of freezing is about seven minutes, except in very warm weather when it requires a few moments longer.

The instrument does not work so satisfactorily in warm weather, owing to the rapid melting of the surface of the preparation. It is absolutely necessary that the mass should be frozen solid, or the sections cannot be cut smoothly.

An extra freezer may be employed, and while one specimen is being cut the other may be frozen, and by exchanging cylinders (they being interchangeable), no delay is necessary to its continuous operation.

The art of cutting is readily acquired, and when the preparation is frozen it is the work of a few moments to obtain several hundred sections. Two hundred sections, or more, if desired, can be made each minute, and of a uniform thickness of about $\frac{1}{200}$ of an inch (thinner or thicker, from about $\frac{1}{2400}$ inch to about $\frac{1}{200}$ inch, according as pointer is set). See explanation of cut No. 1. The delivery, ease and rapidity with which they can be cut, must be seen in order to be appreciated. It is not necessary to remove the sections from the knife every time, but twenty or thirty may be permitted to collect upon the blade; they lie curled or folded up upon the knife, and when placed in water straighten themselves out perfectly in the course of a few hours. The knife I employ is an ordinary long knife from an amputating case. Perfectly fresh tissues may be cut without any previous preparation, using ordinary mucilage (acaciæ) to freeze in, but most specimens require special preparation. If preserved in Müller's fluid, alcohol, etc..

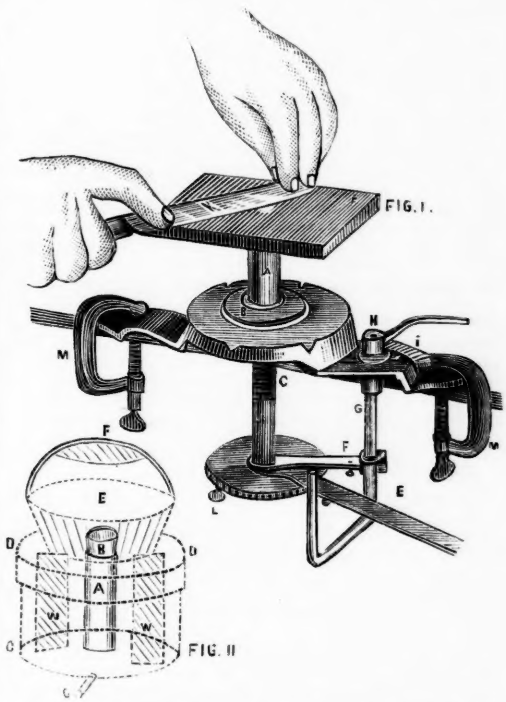

Fig. 1.—Poly-microtome (without freezing apparatus). A, small well, fitting on pyramidal bed-plate; B, pyramidal bed-plate containing different sizes; C, micrometer screw; D, ratchet-wheel attached to screw; E, lever actuating the micrometer screw by means of a pawl engaging in teeth of ratchet-wheel; F, arm carrying a dog, which prevents back motion of screw; G, regulator for limiting the throw of lever, and consequently governing the micrometer screw; H, lever nut for fixing regulator; I, index, with pointer and graduated scale, from $\frac{1}{2400}$ inch to $\frac{1}{200}$ inch; K, knife for cutting sections; L, knob to turn micrometer screw direct when pawls are detached; M, table clamp; T, table cf microtome, with glass top to facilitate cutting.

Fig. 2.—A, B, tube containing specimen which is surrounded by freezing mixture in tin receiver C, D; E, F, revolving hopper with wings; W, W, for stirring the ice; G, outlet for melted ice.

they require to be washed several hours in running water; then, according to the suggestion of my friend, Dr. David J. Hamilton, F.R.C.S., etc.,* University of Edinburgh, Scotland, the specimen is placed in a strong syrup (sugar, two ounces; water, one ounce), for twenty-four hours, and is removed to ordinary mucilage acaciæ for forty-eight hours, and is then cut in the freezing microtome.

The sections may be kept indefinitely in a preservative fluid: ℞ glycerinæ, ℥ iv; aquæ destil ℥ iv; acidi carbolici gtt, iij; boil and filter. (Dr. Hamilton). The addition of alcohol, ℥ ij, is advisable.

* See "A New Method of Preparing Large Sections of Nervous Centres for Microscopical Investigation."—*Journal of Anat. and Phys., Vol. XII.*

CHEMICAL NOTES.

THE OPTICAL PROPERTIES OF MIXTURES OF ISOMORPHOUS SALTS.—H. DUFET has verified the law which he communicated to the Academy, April 8, 1878, *i. e.*, that a crystal formed of a mixture of two isomorphous salts has indices of refraction, which vary continuously with its composition, so that the variation in the value of the index is proportional to the number of equivalents of one of the salts introduced into the mixture.

INFLUENCE OF TEMPERATURE ON THE DISTRIBUTION OF SALTS IN THEIR SOLUTIONS.—In all salts the concentration of the heated portion decreases and that of the cold part increases. The difference thus established increases with the original concentration. In the series of the alkaline chlorides the differerence is so much the greater for the same absolute concentration as the molecular weight is higher. The phenomenon seems to have no relation with the curve of solubility. C. SORET.

RISE OF THE ZERO-POINT IN MERCURIAL THERMOMETERS. —The zero-point rises further and more quickly in thermometers of "crystal" glass than in those free from lead. The rise of the zero-point is much more rapid at the outset, and tends probably towards a limit for a very prolonged heating at a fixed temperature. The effect of an elevated temperature renders the thermometer more stable under the influence of heat at any lower temperature.

J. M. CRAFTS.

DEVELOPMENT BY PRESSURE OF POLAR ELECTRICITY IN HEMIHEDRAL CRYSTALS WITH INCLINED SURFACES.—Whatever may be the determining cause, whenever a hemihedral non-conducting crystal with inclined surfaces occurs, there is a formation of electric poles in a certain direction; whenever the crystal expands the disengagement of electricity takes place in an opposite direction.

MM. JACQUES and PIERRE CURIE.

ACTION OF PERMANGANATE UPON POTASSIUM CYANIDE.—This reaction produces much nitrite and a little urea in an alkaline medium, whilst, if the liquid is acidified with sulphuric acid, urea is formed in abundance. The simultaneous formation of two incompatible compounds, urea and nitrous acid, under the influence of permanganate, shows that the nitrogen of the cyanogen is exposed at once to an oxidising action and to hydrogenisation.

E. BAUDRIMONT.

COMPARATIVE SOLUBILITY OF LEAD PHOSPHATE AND ARSENIATE IN DILUTE ACETIC ACID.—One part of lead arseniate dissolves in 2703.05 parts of dilute acetic acid at 38.94 per cent. One part of lead phosphate requires only 782.90 parts of the same acid. ARMAND BERTRAND.

CAUSE OF THE ACID REACTION OF ANIMAL TISSUES AFTER DEATH.—The acid reaction is due to a decomposition of the fluids in the tissues effected immediately after death by the action of Schizomycetes. At first volatile fatty acids appear to be derived from the incipient decomposition of the albumen, speedily followed by the two lactic acids produced from glycogen. The richer a tissue in carbohydrates, the longer this acid reaction prevails after death, as in the liver, the muscles and the lungs. It is briefest and faintest in the pancreas. In the later hours of putrefaction, the lactic acids disappear and are succeeded by succinic acid. Sooner or later an alkaline reaction sets in throughout the tissues, much ammonia being evolved from the decomposition of the albumen.

MARIE EKUNINA.

CONSTITUTION OF THE SALTS OF ROSANALINE AND OF ANALOGOUS COLORING-MATTERS.—If rosaniline is a triamidic aromatic carbinol its salts will be of two classes: the first series is to be regarded as the ether of a tertiary aromatic alcohol; the second series comprises the salts of this ether, which is itself a triacid amine.

A. ROSENTIEHL.

RESIN OF PALISANDER WOOD.—A. TERREIL and A. WOLFF ascribe to this resin the composition—$C_{21}H_{21}O_8$. It is very soluble in alcohol in all proportions, less soluble in ether, chloroform, and carbon disulphide, and insoluble in water. Nitric acid transforms it into an acid, which crystallizes in very fine orange-yellow needles, united in tufts.

SOLUBILITY OF RECENTLY PRECIPITATED CARBONATE OF LIME IN AMMONIACAL SALTS IN PRESENCE OF AN EQUIVALENT PROPORTION OF SODIUM CHLORIDE.—At the temperature of 10° to dissolve 1 grm. calcium carbonate there are required:

Ammonium hydrochlorate.................	13 980 grms.
" sulphate.........	8.380 "
" nitrate..........................	14.438 "

ARMAND BERTRAND.

PURIFICATION AND REFINING OF FATTY MATTERS.—To determine whether an oil is pure, M. OCTAVE ALLAIRE takes a piece of carbonate of soda (crystal), the size of a nut, dissolves it in its own bulk of water, and shakes it up with the oil under examination in a bottle. If the oil becomes turbid, and gives, on settling, a solid bulky deposit, it has been badly purified. Oils which act upon the metal of lamps and form deposits of verdigris are also to be rejected as impure. Commercial samples often contain 10 to 15 per cent. of free oleic acid.

REMARKS ON THE PLATINUM SULPHOCYANIDE OF V. MARCAGNO.—This body is not a platinum sulphocyanide, but a potassium platino-sulphocyanide, having in its anhydrous state been long ago analysed by M. Buckton. Nor does it yield a proof of the octo-atomicity of platinum, which in this case, as in many others, is tetratomic.

G. WYROUBOFF.

A COMPOUND OF TITANIUM TETRACHLORIDE AND ACETYLE CHLORIDE.—On mixing these two bodies the compound in question is immediately precipitated in small yellow brilliant spangles resembling lead iodide. On exposure to moisture these crystals undergo a change, liberating hydrochloric acid. They may be preserved in dry air, or preferably in dry hydrochloric acid. They melt at 25° to 30° and crystallize on cooling. In contact with alkaline solutions they are decomposed, forming an alkaline acetate and chloride, titanic acid which is precipitated, and water. The analysis of the crystals yielded results agreeing with the formula $C_2H_3OCl+TiCl_4$. ARMAND BERTRAND.

CERTAIN PROPERTIES OF MIXTURES OF METHYL CYANIDE WITH COMMON ALCOHOL AND METHYLIC ALCOHOL.—In order to separate methyl cyanide from alcohol it is necessary to submit the mixture to fractional distillation in order to classify the products; then to dissolve the largest possible quantity of calcium chloride in the mixture, boiling at the lowest temperature in order to absorb the alcohol; then to distil again in the water-bath, and to submit again the product thus obtained to fractional distillation. A very rich cyanide is thus obtained, from which the last traces of alcohol are eliminated by distillation over a small quantity of phosphoric anhydride, and by rectification to remove the small quantity of ethyl oxide and acetate which arise from the reaction of the phosphoric acid.

C. VINCENT and B. DELACHANAL.

DETERMINATION OF UREA BY SODIUM HYPOBROMITE.—C. MEHU criticises the memoirs of M. Fauconnier and M. Jay (*Bulletin de la Soc. Chimique*, xxxiii., pp. 102 and 105). In opposition to the former of these chemists he finds that the presence of cane-sugar distinctly augments the quantity of nitrogen evolved from urea by means of sodium hypobromite. In opposition to M. Jay he considers that it is easy to meet with starch syrups, which give off merely an insignificant quantity of ammonia if heated with caustic soda.

A SEALED paper from the firm of Scheurer-Rott, opened at the last session of l'Académie des Sciences, refers to an improvement in alizarin steam reds, by printing upon pieces previously prepared with emulsive oil, mixed in certain cases with hypochlorite of soda. For producing cadmium sulphide directly upon the fibre, M. Schmid prints a mixture of arsenious acid, sulphur, sodium acetate, and cadmium nitrate. A fine yellow is obtained by steaming for 1 to 2 hours and an orange is produced by increasing the sodium acetate.

A paper by M. Ziegler was opened, recommending an addition of arsenic or boracic acid to the colour beck in dyeing madder reds and roses.